Upset over Air Pollution: Analyzing Upset Event Emissions at Petroleum Refineries

Joshua Ozymy
Texas A&M University–Corpus Christi

Melissa L. Jarrell
Texas A&M University–Corpus Christi

Abstract

The Clean Air Act (CAA) controls routine emissions at petroleum refineries, by creating limits and penalties for excess emissions. The CAA offers provisions for upset events, air emissions released because of unforeseen or unavoidable circumstances, if companies report the emissions and take corrective action. States enforce upset event rules and many states provide exemptions for a variety of circumstances, which may allow upset emissions to become a substantial, yet mostly unregulated source of emissions. We catalog the quantity and type of emissions generated during upset events at 18 Texas petroleum refineries from 2003 to 2008. We find that upset events occur frequently at these facilities and are collectively large in magnitude, emitting a combined total of 75 million lbs of emissions. In a select number of cases, single upset events exceeded annual emissions reported to the Toxics Release Inventory. Future research should assess the accuracy of upset event reporting and impact of upset events on environmental health.

KEY WORDS: environment, governance, health and medicine, industry studies, pollution

Introduction

Research into the health effects of air pollution has yielded sobering results. Childhood asthma rates, respiratory illness, cancer, and heart disease have all been linked to air emissions exposure (Moore et al., 2008; Peng et al., 2009; Pope et al., 2002). A recent American Lung Association report finds that while overall air quality is improving in the United States, approximately half of Americans live in counties that have unhealthful levels of either ozone or particle pollution (American Lung Association, 2011, p. 6). Air pollution is collectively responsible for more than 70,000 deaths each year in the United States (Fischlowitz-Roberts, 2002). Communities living in close proximity to petroleum refineries are especially vulnerable to pollution-related health problems, as they are routinely subjected to harmful air emissions (Burns, Lynch, & Stretesky, 2008).

In order to reduce air emissions produced by major stationary sources of pollution such as oil refineries, the 1970 Clean Air Act (CAA) emphasizes deterrence, by specifying strict limits for how much pollution firms can emit into the environment and auditing, inspecting, and punishing violators for overages (Rosenbaum, 1995). The pure command-and-control approach to regulation is costly to firms, difficult for regulators to enforce, and addressing its deficiencies reached a “critical point” in the early 1990s (Fiorino, 2005). The 1990 CAA Amendments and many related state laws began incorporating a more flexible, cooperative approach into the regulatory regime. Federal and state regulatory agencies work with industry to reduce emissions by waiving penalties for voluntary disclosure. They provide additional compliance incentives in the hopes that industry will self-police, find the most efficient

Review of Policy Research, Volume 28, Number 4 (2011)

means to reduce emissions through innovations in the refining process, and lower enforcement costs to regulators (Potoski & Prakash, 2004; Steinzor, 1998).

A major regulatory dilemma for managing air emissions produced during complex industrial processes at petroleum refineries is controlling routine versus accidental emissions. Routine emissions are easier to predict, making it more feasible to set limits on point source emissions under the CAA. These same facilities also release accidental emissions which are unpredictable and difficult to regulate in the same manner as routine emissions. Moreover, accidental emissions may be outside of the operator's control and the imposition of strict financial penalties may be unfair. Given the absence of significant on-site monitoring and heavy reliance on industry self-reporting of emissions, regulators must provide incentives for firms to voluntarily disclose accurate data and work to correct future accidents (Anderson & Lohof, 1997).

Firms are provided such incentives when states allow nonroutine, accidental emissions to be exempted from penalties when compliant companies promptly report these emissions to regulators and take corrective action to avoid future problems (Environmental Integrity Project, 2004). Upset events (also known as emissions events) are defined as accidental emissions that are generated when an "unanticipated condition at a facility allows materials to escape into the ambient air" (McGarity, 2008, p. 1455). Upset emissions differ from "fugitive emissions," which are defined as emissions stemming from: "leaks from valves, pumps, storage tanks, flanges, etc., and wastewater emissions. . . . Fugitive emissions are those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening" (Environmental Integrity Project, 2007, p. 5).

The Environmental Protection Agency (EPA) allows emissions to be categorized as upsets under the CAA when they occur because of unforeseen events and malfunctions outside of operator control, but provides enforcement discretion to state regulators under their State Implementation Plans (SIPs). As a consequence, "applicable state regulations typically treat excess emissions from startups and shutdowns like upsets, except that they generally require affected facilities to provide prior notice of startups and shutdowns that are expected to release emissions in greater than prescribed amounts" (McGarity, 2008, p. 1456). In Texas, petroleum refineries can report emissions from startups, shutdowns, maintenance, and emissions events as "upsets."[1]

While cooperative and flexible regulatory strategies, such as incentivizing voluntary disclosure of upset events in exchange for waiving penalties, may be mutually beneficial for regulators and firms in the long term, firms have strong incentives to evade regulation absent careful monitoring of voluntary practices (Lenox, 2006; Potoski & Prakash, 2004). If firms can be reasonably certain that state regulators will not check the accuracy of their reporting and the penalties for malfeasance are low, firms may attempt to avoid penalties for excessive emissions across the board by cataloging a host of emissions produced during routine processes as upset events. Alternatively, if state regulators provide broad discretion to refineries to claim a variety of emissions generated from standard operations as upsets, firms may simply generate a substantial amount of exempt emissions legally under state law. Once thought to be an insignificant contribution to overall air emissions at petroleum refineries, upset events may be producing significant amounts of excess emissions.

In this article, we address the absence of policy studies on upset events, by cataloging the amount of air emissions reported by 18 Texas petroleum refineries, from 2003 to 2008. Data on upset events is reported by firms, making it impossible to judge whether all of the emissions disclosed should legally qualify as upset events or if the data is accurately reported. Texas is currently the only reliable data source on upset events, requiring that firms report their upsets to a centralized online database. These limitations aside, we are able to address the impact of upset events on industrial air emissions by specifying the quantity and type of emissions generated at a wide range of refineries in terms of size and refining capacity. To illustrate both the comparative magnitude of upsets to routine emissions and the potential impact of upset events on overall air emissions generated at these refineries, we provide select examples of single upset events that exceed annual on- and off-site emissions of particular chemicals reported to the EPA's Toxics Release Inventory (TRI).

Regulating Air Emissions and Upset Events

Adverse health effects from exposure to air pollution are well documented (Dominici, McDermott, & Hastie, 2004; Litt, Wismann, Resnick, & Dawson, 2007; Moore et al., 2008; Peng et al., 2009; Puett et al., 2008). Childhood and adult respiratory illnesses increase with exposure to toxic air emissions (Moore et al., 2008; Peng et al., 2009), as does heart disease (Peters et al., 2005; Puett et al., 2008). According to a longitudinal study sponsored by the American Cancer Society, greater long-term exposure to air pollution increases the risk of dying from lung cancer and heart disease (Pope et al., 2002). Infants, children, the elderly, and people with weakened immune systems are especially susceptible to the health impacts of air pollution (Collins, 2010). Cancer death rates are highest in areas close to large-scale emitters of air pollution such as petrochemical plants, steel mills, and metal refineries (Situ & Emmons, 2000).

Prior to 1970, most legislation related to air pollution in the United States were generally aimed at determining the nature and extent of the problem, as well as potential methods of dealing with air emissions (Yandle, 1989). By 1970, the command-and-control approach to reducing air emissions from stationary sources of pollution accelerated with the passage of major environmental laws such as the CAA, Clean Water Act, and the Resource Conservation and Recovery Act (Burns et al., 2008). Command-and-control regulation focuses on setting standards and limits, as well as encouraging best available technology requirements for pollution control (Anderson & Lohof, 1997). Enforcing such regulations requires an enforcement system that metes out penalties and sanctions for violations and requires extensive monitoring and inspections. Ultimately, command-and-control regulation is based on deterrence through threat of enforcement for failure to comply with environmental laws and "relies heavily on technical experts" (Fiorino, 2005, p. 7) to create and implement policies.

A firm's environmental performance is contingent on a number of factors aside from regulatory pressure, such as its size, "the nature of its processes and the costs or benefits of pollution control . . . in addition to these internal factors, a facility may face pressures from five external groups: consumers, workers, shareholders, community groups, and regulators" (Harrison & Antweiler, 2003, p. 361). After a decade of pursuing a regulatory style focused on setting limits for air emissions, monitoring firms for compliance, and punishing violators for noncompliance, both regulators and the regulated expressed concern over the efficacy of this approach (Fiorino, 1999). Providing adequate enforcement in an era of expanding environmental mandates and declining departmental budgets made a deterrence-based approach difficult and expensive for regulators (Wood & Waterman, 1993) and industry faced high compliance costs (Walley & Whitehead, 1994). Substantive criticism of command-and-control regulation began focusing on the lack of monitoring and legal loopholes that undermine environmental statutes (Collins, 2010), inability of regulators to severely punish significant and chronic violators of environmental law (Coequyt, Wiles, & Campbell, 1999), and rigid regulatory framework that discourages adoption of best available technology (Fiorino, 2005). Oftentimes firms have little incentive for compliance and industry will choose to pay fines rather than meet the higher costs associated with compliance (Rosenbaum, 1995).

Although the current U.S. environmental regime remains grounded in a command-and-control framework, as early as the 1970s and throughout the past three decades, analysis and discussion of command-and-control policies has suggested that flexible regulation is more effective than direct regulation (Lyon & Maxwell, 2004). For example, in their comprehensive report to the EPA entitled *The United States Experience with Economic Incentives in Environmental Pollution Control Policy*, Anderson and Lohof (1997) provided a meta-analysis of over 30 studies conducted in the 1970s, '80s, and '90s that showed the cost-effectiveness of incentive-based regulation over command-and-control. Adoption of flexible regulation has been slow in coming (Breyer, 1982). The failure to implement more flexible regulation in the 1980s was primarily a by-product of the Reagan administration's efforts at "regulatory reform." As a result, the EPA "expended most of its energies and resources through the 1980s in defending legislation and administrative achievements . . . from the onslaught of President Reagan's regulatory relief" (Rosenbaum, 1995, p. 6). As Yandle (1989) notes, "economic incentives gained a few inches, command-and-control, a few yards" (95). The U.S. experience with environmental regulation is very different than neighboring countries such as Canada, where regulators have traditionally been more receptive to negotiating with polluters (Harrison & Hoberg, 1994), although Canadian regulators have been willing to take the legal route to enforcement when negotiation proves unsuccessful (Harrison, 1995).

Calls for change were prominent in the 1990s (Fiorino, 2005), but any introduction of incentive-based and flexible regulation was often advanced by the states rather than the federal government (Yandle, 1989). The 1990 CAA Amendments did provide for a number of incentive-based mechanisms (i.e., emissions trading, trading acid rain allowances). Environmental policies and regulations that encourage flexible strategies, such as self-reporting of emissions and voluntary compliance have been more widely adopted (Langpap, 2008; Lyon & Maxwell, 2002).

Regulators seek to reduce emissions and enforcement costs, while firms desire lower compliance costs. Both can theoretically produce win-win outcomes over the long term if regulators can trust firms to self-police their behavior and find more efficient ways to reduce compliance costs (Potoski & Prakash, 2005). In a sense, the

EPA and state environmental agencies had to become more flexible with regulation, as they rely heavily on industry self-monitoring and reporting. They do so, as Rosenbaum (1995, p. 201) notes, "in part, because of the sheer volume of regulated entities."

The problem with flexible approaches to regulation involving voluntary disclosure and compliance is that firms have strong incentives to skirt regulation and save on environmental costs rather than properly self-police (Potoski & Prakash, 2004). According to Anderson and Lohof (1997), "voluntary programs are criticized for their lack of teeth, for the fact that firms with already-good environmental records tend to participate but bad actors do not, and for the general lack of accountability (1–7)." Firms may use voluntary programs to delay regulation (Lenox, 2006), "win a lowering monitoring rate or laxer permitting scrutiny from regulators" (Maxwell & Decker, 1998, p. 12), or "free-ride" on the coattails of firms that do engage in voluntary compliance (Fiorino, 2005). Regulators approaching regulation from a more flexible, voluntary standpoint must monitor disclosure to check for accuracy and reduce incentives for malfeasance (Burns et al., 2008). Otherwise, without strong oversight, self-policing alone cannot always reduce emissions (Stretesky & Lynch, 2009).

Regulating air emissions at petroleum refineries under the CAA provides an illustrative example of both command-and-control and flexible strategies at work. The act recognizes 188 hazardous air pollutants (HAPs) that cause or may cause cancer or other serious diseases and illnesses. It sets pollution limits and mandates compliance with those limits; requiring that exceedances of limits be treated as a violation subject to enforcement. States help bring industrial facilities into compliance with the CAA by issuing permits for each major stationary source of pollution.[2] Permits predict maximum allowable emissions rates for each point source, with penalties or other enforcement actions possible for over-the-limit emissions.

Petroleum refineries release both routine and accidental emissions during the refining process. Routine emissions are more predictable and easier to regulate under the basic command-and-control framework of the CAA. Accidental emissions are more difficult to regulate, as they cannot be predicted and are often outside of the operator's control. A unit can release accidental emissions during such circumstances as an equipment malfunction or accident, when a unit is shut down for maintenance and the pollution control equipment become inoperable, or when unforeseen levels of emissions are generated during equipment startup (McGarity, 2008).

Many times, unpredictable emissions are accidentally released during an "upset" and state regulators may take a more flexible approach when regulating these emissions, including requiring facilities to voluntarily report the event in exchange for forgoing penalties or other enforcement actions. The Texas Administrative Code defines upset events as "emissions events, or unscheduled maintenance, startup, or shutdown activities, that result in unauthorized emissions of air contaminants from emissions points" (Public Citizen, 2005, p. 11). The economic benefit to firms for cataloging emissions as upset emissions at refineries is at least two-fold. First, cataloging emissions as upsets avoids penalties traditionally associated with over-the-limit emissions produced by routine operations regulated under the CAA. Second, upset events are often categorized as excess emissions that are

Table 1. Upset Event Rules by State

State Allows Some Upset Emissions to Exceed Permit Limits in State Implementation Plans	Upset Emissions May Not Always Be Included in Emissions Inventories
AL, AK, CO, CT, DC*, FL, GA, IL, IN, IA, KS, KY, LA, MS, ND, NV, NH, NM NY, NH, OH, OR, RI, TX, UT, VA, WA**, WV, WY	AL, AK, AZ, AR, IA, KY, ME, MI, MT, ND, NV, OH, RI, VA

Source: Environmental Integrity Project (2004).
*District of Columbia.
**An exemption is granted, but the scope is unclear.

off-permit and are not included in air permit reviews that set emissions limits on various units at the refinery. “Permit reviews evaluate the proposed emissions from a regulated entity to determine the health impacts to the surrounding communities and the necessary pollution controls. Upset emissions are likely not included in a facility’s potential to emit and, thus, allows facilities to avoid federal requirements they might otherwise be required to meet such an installment of pollution controls” (Public Citizen, 2005, p. 10).

State SIPs provide a variety of rules for upset events. Table 1 displays an overview of these rules. The table demonstrates that 28 states and the District of Columbia allow at least some upset emissions to exceed permit limits. Approximately 14 state regulatory agencies report that their states may not require industry to fully report upset event emissions in their emissions inventories. It remains unclear if the remaining states require and enforce accurate reporting (Environmental Integrity Project, 2004).[3]

Upset event exemptions exist to encourage compliant firms to disclose emissions, in an effort to allow them to undertake corrective actions, rather than always issuing enforcement actions and penalties. Studies undertaken by nongovernmental organizations (NGOs) (Environmental Integrity Project, 2002, 2004, 2005; Public Citizen, 2005), suggest that state regulators allow a wide range of scenarios to qualify as upsets and are not monitoring the accuracy of upset event disclosures or pursuing enforcement actions against firms that misuse the exemption without pursuing corrective action. States may be “racing to the bottom” by relaxing environmental standards and enforcement in an effort to attract and maintain industrial development (Potoski, 2001). Alternatively, state regulators may simply lack the resources to monitor upset event reporting or allow a wide range of scenarios to qualify as upsets.

For example, three separate studies by the Environmental Integrity Project (2002, 2004, 2005) find that emissions were generated frequently during upset, and some pollutants exceed their annual emissions inventories for that pollutant (by more than 25 percent in some cases). Another 2003 study of Texas facilities by Public Citizen (2005) supports this conclusion that upset event emissions can meet or exceed those emissions emitted during routine operations at industrial facilities. We expand and update these studies by creating a much larger dataset allowing us to analyze the frequency and amount of upset event emissions at 18 petroleum refineries, 2003–08. We then provide examples of the comparative magnitude of upset emissions to routine emissions, by comparing the emissions generated during particular upset events to those emissions submitted to the TRI.

Data and Analysis

Data for the study were gathered through content analysis from the Texas emission event database accessible through the Texas Commission on Environmental Quality (TCEQ) website.[4] Beginning January 31, 2003, the Texas legislature mandated that industry submit reports of emissions occurring during upset events electronically to the TCEQ within 24 hours of the event. The data are then made available to the public within days of the submission, as are corrections to the reports that must be submitted within 2 weeks.

Retrieving data on upset events in all other states is a laborious and expensive process that requires obtaining hard copies of upset event reporting forms through freedom of information requests. Data collection problems are further exacerbated given that many refineries produce thousands of air discharges through upsets annually, state regulators may not agree to disclose information on upsets, or the physical reports themselves may be damaged (Environmental Integrity Project, 2002, 2004). Mandatory online reporting makes Texas the only readily available and accurate data source on upset events. It is important to note that the data are voluntarily reported by industry, which suggests that the data may be conservative in nature (Waxman, 1999).

Each upset event report displays the following: the type of event (an equipment startup, shutdown, maintenance, or emissions event), the source of the event (i.e., storage tank leaks, flare-offs, boiler startups, or other equipment maintenance or malfunctions), the material(s) emitted, the amount, the start and end date of the event, and the method of calculation for the discharge of emissions. Every upset event available online from January 31, 2003 to December 31, 2008 was downloaded and these variables coded for 18 petroleum refineries. In order to assess 2003 in its entirety, we supplemented the online database, including data provided by regulators on all upsets beginning in January of that year that are not available online. Altogether, the dataset contains approximately 38,000 cases.

We chose to analyze petroleum refineries because refineries are the fourth largest producer of air emissions and largest producer of volatile organic compounds (VOCs) in the nation (Waxman, 1999). While Texas is the only source of readily available data, most oil refineries in the United States are located within Texas, Louisiana, and California. Texas is home to more petroleum refineries than any other state in the country allowing us to choose from a broad array of facilities in terms of size, location, and refining output.

Findings

We begin the analysis by displaying upset event trends across all 18 refineries from 2003–08. The 18 facilities in the analysis are listed in Table 2. Our sample ranges across the state from El Paso (Western Refining) to Houston (Valero).This sample contains the largest petroleum refinery in the United States in terms of daily refining capacity, Exxon-Mobil Baytown at 572,500 barrels per day, mid-level

Table 2. Total Emissions Released during Upset and Refining Capacity for 18 Texas Petroleum Refineries, 2003–08

Facility	Location	Total Upset Emissions (lbs)	Refining Capacity (Barrels/Day)
Exxon-Mobil Refining and Supply CO	Baytown	11,754,389	572,500
BP Products North America INC	Texas City	4,971,330	455,790
Exxon Refining and Supply CO	Beaumont	10,065,247	344,500
Shell/Deer Park Refining LTD	Deer Park	4,914,496	329,800
Valero Energy Corporation	Port Arthur	5,762,014	287,000
Motiva Enterprises LLC	Port Arthur	3,108,320	285,000
Houston Refining LP	Houston	942,669	270,600
Total Petrochemicals INC	Port Arthur	13,646,204	232,000
Valero Refining CO Texas LP	Texas City	1,872,487	199,500
Valero Energy Corporation	McKee/Sunray	196,680	171,000
ConocoPhillips/WRB Refining LLC	Borger	4,909,850	146,000
Western Refining Company LP	El Paso	1,050,091	122,000
Pasadena Refining Systems INC	Pasadena	288,914	100,000
Valero Energy Corporation	Three Rivers	440,790	93,000
Valero Refining CO Texas LP	Houston	3,081,171	83,000
Marathon Petroleum CO LLC	Texas City	106,732	76,000
Alon USA Energy Inc	Big Spring	5,830,847	67,000
Delek Refining LTD	Tyler	2,613,400	58,000

producers such as Conoco-Phillips Borger at 146,000 barrels per day, and smaller facilities such as Delek Refining in Tyler at 58,000 barrels per day. While limited to Texas, this represents a wide variation in refinery size and output.

The total amount of emissions released during upset at these refineries from 2003 to 2008 is displayed in pounds in the third column of Table 2. These amounts ranged from over 13 million lbs at the Total facility in Port Arthur to approximately 196,000 lbs at the Valero facility in McKee. While there is a trend between refining capacity and upset event emissions in our dataset, it is not very strong. Delek is the smallest refiner with a refining capacity of 58,000 barrels per day and generating over 2.6 million lbs of upset emissions. The Valero Texas City refinery has over three times the refining capacity of Delek, yet generated 1.8 million lbs of upset emissions. The Total refinery has a refining capacity just slightly higher than the Valero Texas City plant, but generated seven times the amount of upset emissions. The BP Texas City refinery has the second largest refining capacity in the dataset (455,790 barrels per day), but generated a roughly equivalent amount of emissions to the ConocoPhillips plant in Borger with only a 146,000 barrels per day refining capacity.

Although the small amount of refineries in our dataset limits our ability to generalize about the connection between refinery output and upset emissions at other facilities across the United States, it appears in our analysis that upset emissions are not strongly linked to refinery output. This finding suggests that the amount of upset emissions generated at a petroleum refinery may be explained by other factors. While we cannot explore the possibility with our dataset, one factor in predicting upset emissions may be the variation in the amount of equipment failures or lack of equipment upkeep and maintenance at certain petroleum refineries. Given that upset events are reported by refineries, some facilities may simply be more vigilant in reporting upsets or more generous in their engineering estimations.

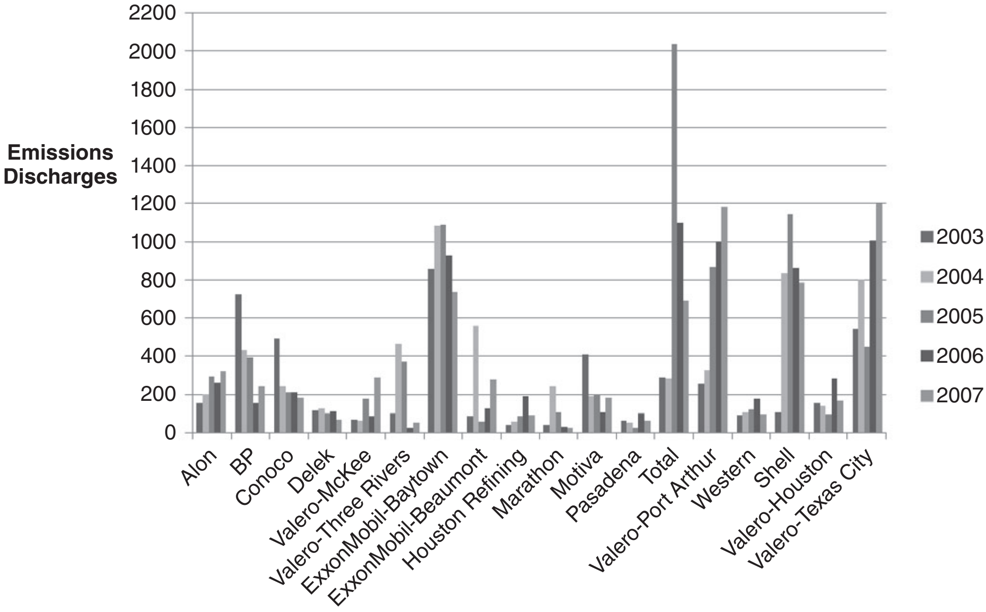


Figure 1. Frequency of Emissions Discharges Occurring during Upset Events at 18 Texas Petroleum Refineries, 2003–08

We now turn to examining the frequency of upset events at these refineries. Listing the frequency of upsets alone is misleading.[5] Upset events release numerous emissions of varied amounts and have no particular time frame. We start by displaying the actual frequency of air emissions discharges at each refinery in Figure 1.

The figure demonstrates that air emissions generated during upsets are quite common across refineries over time. In 2003, for example, the Alon facility released 155 emissions during upset, while increasing that number to 197 in 2004, 290 in 2005, and hitting a peak in 2007 at 322.[6] The BP plant released 721 emissions in 2003, while producing 1,020 in 2008. The largest amount of discharge stems from the largest refinery (ExxonMobil Baytown), producing over 5,700 emissions during upsets over the 6-year period of the study. The largest single-year emissions total was produced by the Total facility, which produced 2,035 emissions in 2005. The total combined emission discharges for the refineries is shown in Figure 2. Over time, the emission discharge trend has increased from 4,547 in 2003, to 6,172 (2004), a high of 7,795 (2005), 6,728 (2006), 6,610 (2007), and 6,122 in 2008 for a total of 37,974 emission discharges.

Upset events can release a host of chemicals into the environment at considerably varying amounts and over varied lengths of time. In fact, most upsets in our dataset resulted in a series of emissions, regardless of the source or length of the event. The vast majority of the emissions were in the form of sulfur dioxide (SO_2) and carbon monoxide (CO). Although too numerous to list for each particular refinery, a number of petrochemical-based compounds were emitted in addition to SO_2 and CO emissions. The following is an example of these compounds emitted by the Delek facility: 1-butene, butane N-, ethane, ethylene (gaseous), hexane plus, hydrogen sulfide, i-pentane, isobutane, methane, nitrogen dioxide, nitrogen oxide,

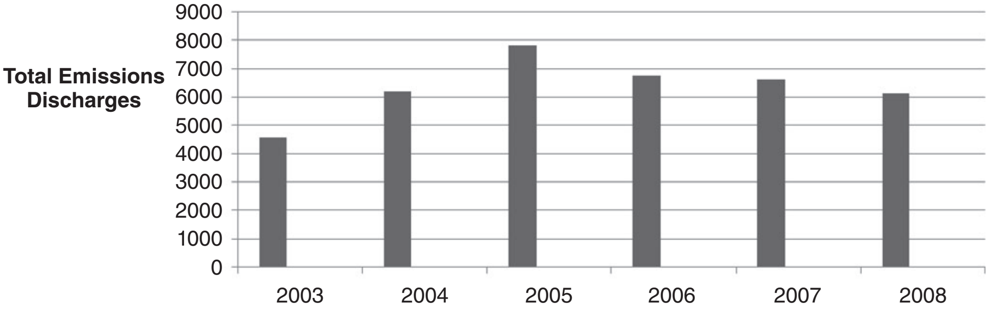


Figure 2. Total Combined Emissions Discharges Occurring during Upset Events at 18 Petroleum Refineries, 2003–08

n-pentane, pentane, propane, propylene (propene), smoke (measured as opacity), sulfur trioxide, and VOCs (light hydrocarbons).

The refineries in our dataset emitted SO_2 in very large quantities (over 32 million lbs), representing 42 percent of overall emissions. Carbon monoxide was the second largest source of air pollution at approximately 23 million lbs or 31 percent of the total. The remaining 27 percent represent a host of chemicals and VOCs at over 20 million lbs. Overall, we estimate that an approximate grand total of 75,555,630 lbs of air emissions were generated during upset events in the analysis.

Figure 3 lists the aggregate amounts of SO_2 and CO in pounds, generated at each refinery from 2003 to 2008. Breaking down these aggregate emissions by pollutant and year shows that the Alon facility's SO_2 emissions ranged from 600,000 lbs (2006) to slightly under 100,000 lbs (2003). CO emissions were highest in 2003 (over 1.2 million lbs) and additional emissions topped out at 425,000 lbs in 2008. Exxon-Baytown emitted over 1.3 million lbs of SO_2 in 2003, 349,000 lbs in 2004, while only emitting 114,000 lbs through upset in 2007, drastically increased to over 900,000 lbs the following year; it more than tripled its CO emissions from 2004 (590,000) to 2005 (2,000,000). By far the largest single-year and overall emitter of SO_2 in the sample was the Total facility in Port Arthur. In 2003, it released a trendsetting 6,222,439 lbs of this air pollutant and over 10 million lbs in the course of 6 years, while the Marathon facility emitted no SO_2 during upset 2006–08.

Total, Shell, Valero-Port Arthur and Houston, Motiva, ExxonMobil-Baytown, and BP all emitted large amounts of emissions besides SO_2 and CO. The largest emitter was BP at over 3.1 million lbs, followed by Valero-Houston (2.5 million), Total (2.5 million), Motiva (approximately 2.4 million), Shell (over 1.9 million), ExxonMobil-Baytown (1.6 million), and Valero-Port Arthur (1.4 million). Many of these facilities recorded these emissions across a series of very frequent discharges. ExxonMobil-Baytown, for example, recorded 4,424 discharges in 6 years, Shell 4,081, and Valero-Port Arthur 3,483. Valero-Texas City claimed 3,891 discharges for only 702,000 lbs of emissions for a mere 180 lbs/discharge average. Delek produced only 25,735 lbs of additional emissions.

What factors account for the large differences in upset emissions across these refineries? As noted above, because upset event reporting is self-reported, some refineries may simply be better reporters than others. Variation in refinery size does

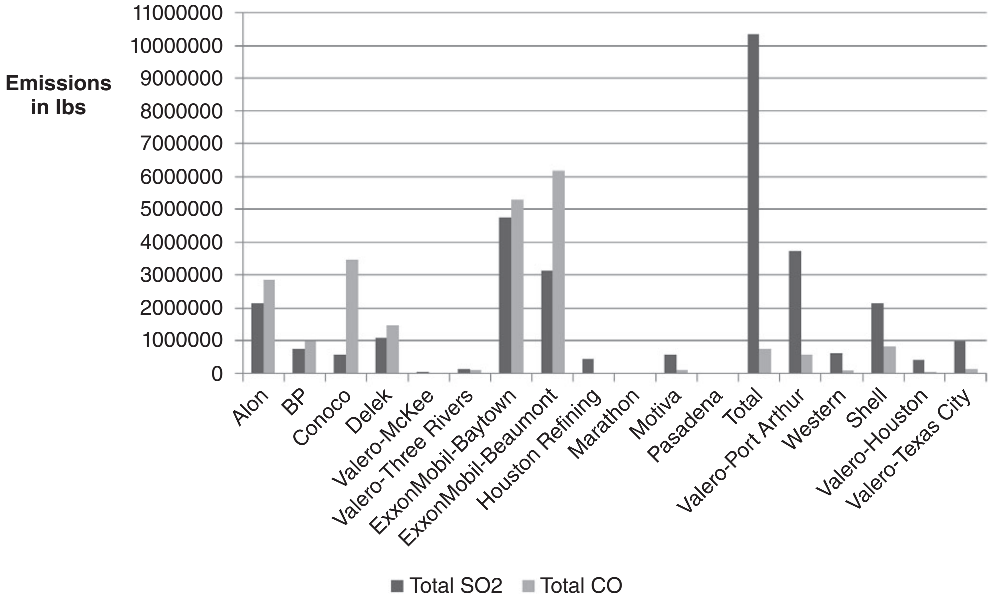


Figure 3. Total SO_2 and CO Emissions Generated during Upset by Refinery, 2003–08

not appear to be a primary factor. Upkeep of equipment may be an important predictor of upset emissions that cannot be explored with the present data.

Large upset events are one variable we identified in our dataset that can help to explain the variation in aggregate upset emission totals at these refineries. Table 3 provides some examples of major, single-emissions occurring during upset in the sample. The Alon facility experienced at least five such events, where over 200,000 lbs of material was emitted. In two equipment start-ups at the BP facility, over 1.3 million lbs of propane/pentane was emitted. Emissions events at the ExxonMobil-Beaumont facility released 1.8 and 1.1 million lbs of CO into the atmosphere, while its sister plant in Baytown released 600,000 lbs in one event. Much of the reason for why the Total facility released such a high degree of SO_2 (over 10 million lbs) stems in great part from three emissions events listed in the table that generated almost half of that amount. Valero-Houston released 2.5 million lbs of additional pollutants in 6 years outside of SO_2 and CO. Yet, that number obscures the fact that half of this amount (1,395,000 lbs of isobutane) was generated during one emissions event.

We now provide illustrative examples of the overall magnitude of upset event emissions compared with routine emissions, by comparing our upset event data with emissions these refineries report to the TRI; however, although reports suggest that refineries may not fully include upset emissions in their emissions inventory levels (Environmental Integrity Project, 2004), we cannot assess the overall accuracy of this claim. Finding examples of upset event emissions that exceed data reported to the TRI for a particular compound in a given year is suggestive of possible inaccurate reporting, but it could just as easily result from error that occurs in all large datasets. Moreover, a majority of the emissions from the refineries in our dataset are in the form of SO_2 and CO, neither of which is reported to the TRI. A general review of the dataset can provide select examples of overages

Table 3. Examples of Large Upset Events at 18 Texas Petroleum Refineries, 2003–08

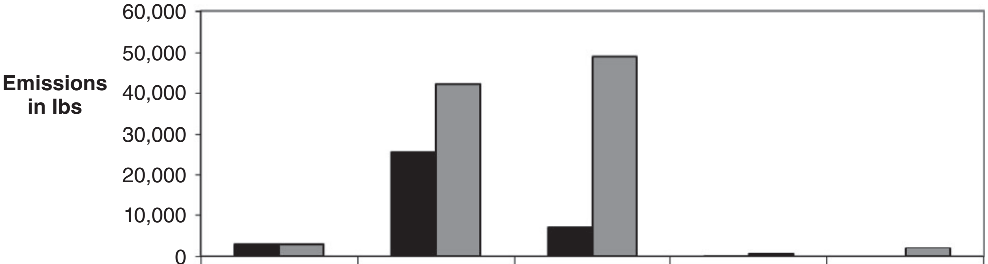
Refinery	Event Type	Source	Material	Amount*
Alon	Emissions event	FCCU CO Boiler	Carbon monoxide	408,248.29
	Maintenance	FCCU CO Boiler	Carbon monoxide	875,388.99
	Maintenance	FCCU CO Boiler	Carbon monoxide	260,682.06
	Emissions event	01TANK0209	Particulate matter	310,242.35
	Emissions event	01TANK0209	Carbon monoxide	324,561.22
BP-Texas City	Air startup	Temp Flare	Propane	719,937.00
	Air startup	Temp Flare	Pentane	615,453.00
	Air startup	Temp Flare	Butane	320,483.00
	Air startup	Electrostatic Prec. Stack	Carbon monoxide	300,000.00
Conoco Delek	Emissions event	U40 CO Boiler stack	Carbon monoxide	302,000.00
	Emissions event	#2 Cat Flare	Carbon monoxide	477,953.00
	Emissions event	#2 Cat Flare	Carbon monoxide	161,769.00
	Emissions event	#2 Cat Flare	Carbon monoxide	154,415.00
ExxonMobil Baytown	Air startup	Flare26	Carbon monoxide	602,847.00
	Air startup	Flare22	Sulfur dioxide	426,863.00
	Emissions event	Flare 26	Sulfur dioxide	357,624.00
ExxonMobil Beaumont	Emissions event	FCC Scrubber Stack	Carbon monoxide	1,844,308.00
	Emissions event	FCCU Scrubber Stack	Carbon monoxide	1,103,100.00
	Emissions event	Wet Gas Scrubber	Carbon monoxide	964,239.00
Motiva	Maintenance	FCCU3 Regenerator	Nitrogen oxide	411,200.00
	Emissions event	3FCCU Cooling Tower	Propylene	403,759.62
Shell	Emissions event	Coker Flare	Sulfur dioxide	516,068.00
	Emissions event	Coker Flare	Sulfur dioxide	327,726.00
Total	Emissions event	North Flare	Sulfur dioxide	2,591,492.00
	Emissions event	Refinery North Flare	Sulfur dioxide	1,683,347.66
	Emissions event	North Flare	Sulfur dioxide	764,859.11
Valero-Houston	Emissions event	Cooling Tower No. 3	Isobutane	1,395,318.00
Valero-Port Arthur	Emissions event	23 Flare	Sulfur dioxide	261,144.42

*Data reported in pounds.

that can, at a minimum, suggest the comparative magnitude of upset emissions to on and off-site emissions reported to the TRI.

In Figure 4, we provide five examples of upset events that exceed the annual on and off-site amount of that specific chemical each of these refineries reported to the TRI that year. The first column shows that in 2007, the ExxonMobil Baytown facility reported 2,900 lbs of Cyclohexane to the TRI. Yet one upset event at the facility that year generated 3,007 lbs of Cyclohexane (column two) or 104 percent of the total value. As shown in column three, in 2005, the Shell Deer Park facility reported 25,690 lbs of Benzene (a known carcinogen) to the TRI, but a single upset event that year produced 42,077 lbs. The BP Texas City facility reported 7,250 lbs of 1,3-butadiene in 2006, but one upset event released 49,037 lbs (676 percent of the value). We also discovered that the Valero facility in Port Arthur (Premcor at the time) reported 41 lbs of styrene to the TRI in 2004, but reported 588 lbs during one upset (1434 percent of the value). Finally, in 2006 the Total refinery reported an upset event in August that generated 2,013 lbs of Cyclohexane, while reporting no releases to the TRI. In the Shell case above, one upset event in 2005 produced more benzene that the facility reported to the TRI in 2005 and 2006. From 2003 to 2008, the facility reported 113,664 lbs of Benzene to the TRI, while reporting approximately 99,249 lbs as upset events.

Neither SO_2 nor CO is reported to the TRI, making it difficult to compare upset event emissions to each facility's overall reported emissions as in Figure 3. Instead, we attempted to place the impact of upset events in a real-world context. We



	ExxonMobil Cyclohexane 2007	Shell Benzene 2005	BP 1,3-Butadiene 2006	Valero Styrene 2004	Total Cyclohexane 2006
■ Total Reported to TRI	2,900	25,690	7,250	41	0
▩ Single Upset Event	3,007	42,077	49,037	588	2,013

Figure 4. Comparing Toxics Release Inventory Data to the Texas Emissions Event Database

demonstrated how much CO some of these large, single upset events produce by comparing the emissions to those generated by passenger cars. The EPA estimates that the average passenger vehicle, traveling 12,500 miles per year, produces 606 lbs of CO.[7] Figure 5 shows that one event on March 22, 2003 at the BP-Texas City facility produces enough CO to replace 495 cars traveling 12,500 miles each that year. On February 9, 2004, an upset event at the Alon facility produced equivalent CO to that of 1,445 passenger cars. On May 16, 2004, an upset at the ExxonMobil-Beaumont refinery generated a massive amount of CO, equivalent in magnitude to that of 3,043 cars. Combined, these seven events listed in this table produced more CO than 10,178 passenger cars over this time period. All 18 refineries generated enough CO to replace 38,067 passenger cars.

Conclusion

Currently, the policy literature has focused a considerable amount of effort on examining how federal and state regulators manage routine emissions at large industrial complexes, but has not addressed the issue of accidental emissions. The original CAA was a mere 68 pages in length. The 1990 Amendments totaled almost 800 pages; "regulations required for their implementation will exceed 10,000 pages" (Rosenbaum, 1995, p. 14). As a result, it is not surprising that the policy implications of upset events did not come to light until NGOs like Public Citizen (2005) and the Environmental Integrity Project (2004) took advantage of newly available data on upsets in Texas to explore the issue. Texas allows a range of functions at oil refineries and other industrial complexes to qualify as upsets when over-the-limit emissions are released during emission events, maintenance, and equipment startups and shutdowns (McGarity, 2008). The important public policy implication of our study is whether upset events result in significant emissions that deserve the attention of policy analysts, administrators, elected officials, and the general public.

We chose to study petroleum refineries, as they are the fourth largest emitter of air pollution and largest generator of VOCs in the country (Waxman, 1999). Although confined to Texas (because of data limitations in other states), we are able

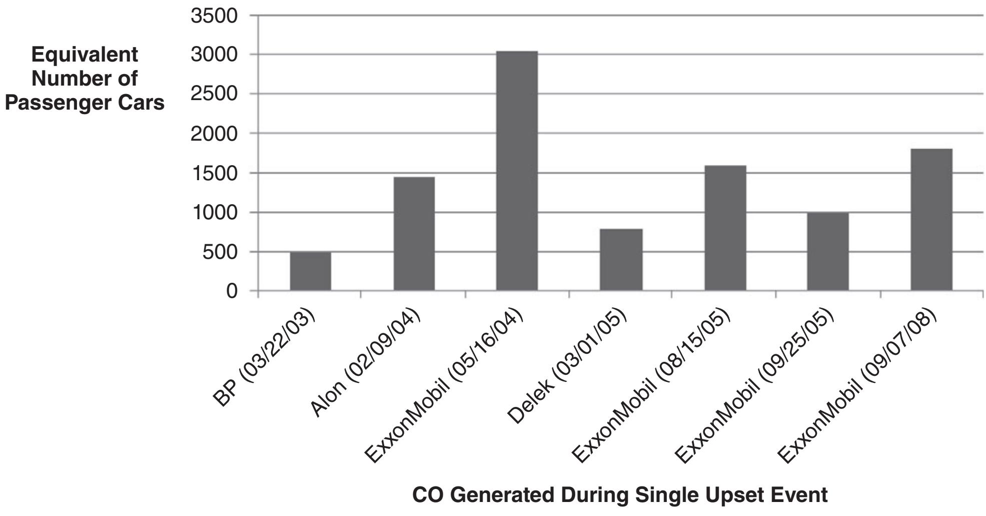


Figure 5. Comparing CO Emissions Generated during Single Upset Events to Yearly Passenger Vehicle CO Emissions

to choose a broad range of companies and refineries in terms of refining output. Our findings suggest that, taken together, these petroleum refineries generated a sizable amount of air emissions during upset. Upsets are also fairly frequent occurrences with no nonstandard time frames, lasting from a few minutes to months. Taken individually, size is not a strong indicator of a refinery's propensity to generate upset emissions. It appears to be the case, at least in our limited sample, that total emissions generated during upset are more specific to each refinery, suggesting other factors such as newer equipment, better maintenance practices for equipment, or simply more accurate reporting might better explain a facility's upset emissions.

We found it interesting that many of the emissions we cataloged were produced during very massive upset events. Many of these events produced as much as 2.5 million lbs of SO_2 (Total facility) in one upset. Of all the thousands of air emissions generated at these facilities, most were in the form of SO_2 and CO. While we cataloged approximately 75 million lbs of emissions produced during upset in our analysis, we also demonstrated select examples where just one upset event at a refinery produces more of a particular emission than the refinery reported to the TRI in a given year. One such example is in 2005 when the Shell facility reported 25,690 lbs of benzene to the TRI, but one single upset event at the facility that year generated over 42,000 lbs of benzene. Both the overall data and these select examples demonstrate the propensity of upset events to generate large amounts of air pollution, frequently, and should be given greater attention in the policy dialogue over regulating air emissions.

We suggest that a proper policy proposal regarding upsets should start with transparency. States should require easily accessible online reporting of upset events. State and federal regulators should require that the industry submit any and all emissions to the TRI, regardless of the intent to penalize these excess emissions. Measuring air pollution and assessing health risks require complete data.

The issue of accuracy remains problematic as the data are self-reported by the industry. State regulators should forego such a heavy reliance on industry self-reporting and engage in additional direct monitoring and oversight of air emissions at industrial facilities (Stretesky & Lynch, 2009); however, although many firms engage in voluntary compliance, the industry has a strong financial incentive to underreport emissions, especially absent consistent direct oversight and infrequent enforcement. For example, a past congressional study (Waxman, 1999) found that the industry routinely underreported valve and equipment leaks of fugitive emissions. Monitoring of facilities with attached penalties for over-the-limit emissions or careful monitoring of voluntary disclosure practices is crucial.

We recognize that requiring easily accessible online reporting of upset events will not necessarily solve the problem of excess emissions. In addition, direct monitoring and increased oversight are challenging objectives. It is unlikely that the EPA and regulatory agencies will see increased budgets in the near future. Most states are experiencing budget crises. We agree with researchers such as Fiorino (2005) that new regulations need to "take into account the limited resources and capacities of government, while aiming to use industry's knowledge and motivation more effectively" and that if we continue to debate regulation in a simplistic pro/anti fashion, we will not see much in the way of progress.

While it is not our intent in the present study to provide ultimate solutions to the problem of upset events and environmental regulation, we agree with prior research that environmental regulation needs to combine beneficial aspects of command-and-control practices with more flexible, innovative, and incentive-based approaches. Regulatory agencies are overwhelmed, at best, and without more governmental support, are limited in their capacity to regulate industry. With more access to public data, researchers with universities, interest groups, and NGOs are more likely to utilize the data that could assist the EPA and other regulatory agencies. Regulatory agencies could certainly use the help. Why not engage the public in efforts to combat environmental violations, similar to community policing initiatives aimed at combating street crime?

Notes

1 See Texas Administrative Code for a description of state rules for qualifying emissions events and reporting: http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=101&rl=201

2 Major stationary sources of pollution are those that emit 10 tons or more per year of any criteria pollutant, and 25 tons per year of any combination of HAPs as listed under the National Ambient Air Standards.

3 According to a survey of state environmental regulators (Environmental Integrity Project, 2004) the following states do not require or only partially require reporting of upset event emissions to emission inventories: AL, AK, AZ, AR, KY, ME, MI, MT, NV, OH, RI, VA. Additionally, ND "generally" requires reporting and IA mandates reporting for Title V sources. According to the survey, it is unclear if Minnesota allows upset emissions to exceed permit/rule limits.

4 The database can be accessed at: http://www11.tceq.state.tx.us/oce/eer/index.cfm

5 In certain cases, refineries report opacity and note the level of opacity displayed in percentage. Given that the unit of measurement is not comparable with all other emissions, which are reported in pounds, we excluded them from the analysis.

6 We report upsets in the analysis based on the start date of each event.

7 This estimate was based on 22 g of CO generated per mile at an average mileage of 12,500 per year. The calculation is then: 22*12,500 = 275,000*.0022046 or 606 lbs/year. Retrieved from: http://msl1.mit.edu/EPA-average-ann-emit.pdf

About the Authors

Joshua Ozymy is an Assistant Professor of Political Science at Texas A&M University-Corpus Christi. His research focuses on environmental politics and participatory behavior.

Melissa L. Jarrell is an Assistant Professor of Criminal Justice at Texas A&M University-Corpus Christi. She received her M.A. and Ph.D. in Criminology from the University of South Florida. Dr. Jarrell is the author of Environmental Crime and the Media: News Coverage of Petroleum Refining Industry Violations. Her research interests include environmental justice, corporate crime, and crime and the media. She works with local communities and grassroots environmental justice activists to address issues of poverty, pollution, and injustice.

References

American Lung Association. (2004). State of the air 2011. Retrieved from http://www.stateoftheair.org/2011/assets/SOTA2011.pdf (accessed May 12, 2011).

Anderson, R. C., & Lohof, A. (1997). *The United States experience with economic incentives in environmental pollution control policy*. Washington, DC: Environmental Law Institute.

Breyer, S. (1982). *Regulation and its reform*. Cambridge, MA: Harvard University Press.

Burns, R. G., Lynch, M. J., & Stretesky, P. B. (2008). *Environmental law, crime, and justice*. New York: LFB Scholarly.

Coequyt, J., Wiles, R., & Campbell C. (1999). *Above the law: How the government lets major air polluters off the hook*. Washington, DC: Environmental Working Group.

Collins, C. (2010). *Toxic loopholes: Failures and future prospects for environmental law*. New York: Cambridge University Press.

Dominici, F., McDermott, A., & Hastie, T. (2004). Improved semi-parametric time series analysis of air pollution and mortality: A statistical review. *Journal of American Statistical Association*, *468*, 938–948.

Environmental Integrity Project. (2002). Accidents will happen: Pollution from plant malfunctions, startups, and shutdowns in Port Arthur, Texas. Retrieved from http://www.environmentalintegrity.org/pdf/publications/Report_Accidents_Will_Happen.pdf (accessed May 12, 2011).

Environmental Integrity Project. (2004). Gaming the system: How off-the-books industrial upset emissions cheat the public out of clean air. Retrieved from http://www.environmentalintegrity.org/pdf/publications/Report_Gaming_the_System_EIP.pdf (accessed March 1, 2010).

Environmental Integrity Project. (2005). Off the books: Air pollution missing from Texas annual emission inventory. Retrieved from http://www.environmentalintegrity.org/pdf/publications/Report_Off_The_Books.pdf (accessed March 1, 2010).

Environmental Integrity Project. (2007). Comments on proposed national emission standards for hazardous air pollutants from petroleum refineries. Retrieved from http://www.environmentalintegrity.org/pdf/publications/Joint_Comments_NRDC_EJ_EIP_GHASP_EPCA_MCA_SEED_6.pdf (accessed May 12, 2011).

Fiorino, D. J. (1999). Rethinking environmental regulation. *Harvard Environmental Law Review*, *23*, 441–469.

Fiorino, D. J. (2005). *The new environmental regulation*. Cambridge, MA: The MIT Press.

Fischlowitz-Roberts, B. (2002). Air pollution fatalities now exceed traffic fatalities by 3 to 1. Retrieved from http://www.earth-policy.org/index.php?/plan_b_updates/2002/update17 (accessed February 1, 2011).

Harrison, K. (1995). Is cooperation the answer? Canadian environmental enforcement in comparative context. *Journal of Policy Analysis and Management*, *14*, 221–245.

Harrison, K., & Antweiler, W. (2003). Incentives for pollution abatement: Regulation, regulatory threats, and non-governmental pressures. *Journal of Policy Analysis and Management*, *22*, 361–382.

Harrison, K., & Hoberg, G. (1994). *Risk, science, and politics: Regulating toxic substances in Canada and the United States*. Montreal: McGill-Queen's University Press.

Langpap, C. (2008). Self reporting and private enforcement in environmental regulation. *Environmental and Resource Economics*, *40*, 489–506.

Lenox, M. (2006). The prospects for industry self-regulation of environmental externalities. Retrieved from http://faculty.darden.virginia.edu/LenoxM/pdf/isr_theory2.pdf (accessed May 12, 2011).

Litt, J. S., Wismann, A., Resnick, B., & Dawson, R. S. (2007). Advancing health and environmental disease tracking: A 5-year follow-up study. *American Journal of Public Health*, *97*, 456–463.

Lyon, T. P., & Maxwell, J. W. (2002). Voluntary approaches to environmental regulation. In M. Franzini & A. Nicita (Eds.), *Economic institutions and environmental policy* (pp. 142–174). Aldershot: Ashgate Publishing Company.

Lyon, T. P., & Maxwell, J. W. (2004). *Corporate environmentalism and public policy*. Cambridge: Cambridge University Press.

Maxwell, J. W., & Decker, C. S. (1998). Voluntary environmental investment and regulatory flexibility. As cited in T. P. Lyon & J. W. Maxwell. (2002). Voluntary approaches to environmental regulation. In Maurizio Franzini & Antonio Nicita (Eds.), *Economic institutions and environmental policy*. Aldershot: Ashgate Publishing Company.

McGarity, T. O. (2008). Hazardous air pollutants, migrating hot spots, and the prospect of data-driven regulation of complex industrial complexes. *University of Texas Law Review*, *86*, 1445–1492.

Moore, K., Neugebauer, R., Lurmann, F., Hall, J., Brajer, V., Alcorn, S., et al. (2008). Ambient ozone concentrations cause increased hospitalizations for asthma in children: An 18-year study in Southern California. *Environmental Health Perspectives*, *116*, 1063–1070.

Peng, R., Bell, M., Geyh, A., McDermott, S., Zeger, S., Samet, J., et al. (2009). Emergency admissions for cardiovascular and respiratory diseases and the chemical composition of fine particle air pollution. *Environmental Health Perspectives*, *117*, 957–963.

Peters, A., Von Klot, S., Heier, M., Trentinaglia, I., Cyrys, J., Hormann, A., et al. (2005). Particulate air pollution and nonfatal cardiac events. *Respiratory Report of Health Effects Institute*, *124*, 1–66.

Pope, C. A., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., et al. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA*, *287*, 1132–1141.

Potoski, M. (2001). Clean air federalism: Do states race to the bottom? *Public Administration Review*, *61*, 335–342.

Potoski, M., & Prakash, A. (2004). The regulation dilemma: Cooperation and conflict in environmental governance. *Public Administration Review*, *64*, 137–148.

Potoski, M., & Prakash, A. (2005). Green clubs and voluntary compliance: ISO 14001 and firms' regulatory compliance. *American Journal of Political Science*, *49*, 235–248.

Public Citizen. (2005). Industrial upset pollution: Who pays the price? Retrieved from http://www.citizen.org/documents/08.01.05%20Industrial%20upsets%20report.pdf (accessed May 12, 2011).

Puett, R. C., Schwartz, J., Hart, J. E., Yanosky, J. D., Speizer, F. E., Suh, H. H., et al. (2008). Chronic particulate exposure, mortality, and coronary heart disease in the nurses health study. *American Journal of Epidemiology*, *168*, 1161–1168.

Rosenbaum, W. A. (1995). *Environmental politics and policy*. Washington, DC: CQ Press.

Situ, Y., & Emmons, D. (2000). *Environmental crime: The criminal justice system's role in protecting the environment*. Thousand Oaks, CA: Sage.

Steinzor, R. I. (1998). Reinventing environmental regulation: The dangerous journey from command to self-control. *Harvard Environmental Law Review*, *22*, 1–103.

Stretesky, P. B., & Lynch, M. J. (2009). Does self-policing reduce chemical emissions? A further test of the EPA self audit policy. *The Social Science Journal*, *46*, 459–473.

Walley, N., & Whitehead, B. (1994). It's not easy being green. *Harvard Business Review*, *72*, 46–51.

Waxman, H. A. (1999). Oil refineries fail to report millions of pounds of harmful emissions. Report Prepared for Rep. Henry A Waxman November 10, 1999 by the U.S. House of Representatives Minority Staff, Special Investigations Division, Committee on Government Reform.

Wood, B. D., & Waterman, R. W. (1993). The dynamics of political bureaucratic adaption. *American Journal of Political Science*, *37*, 497–528.

Yandle, B. (1989). *The political limits of environmental regulation*. New York: Quorum Books.